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JOURNAL

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Contents:

"OXY-ACETYLENE WELDING"

by F. CLARK, M.B.E., M.Inst.W.

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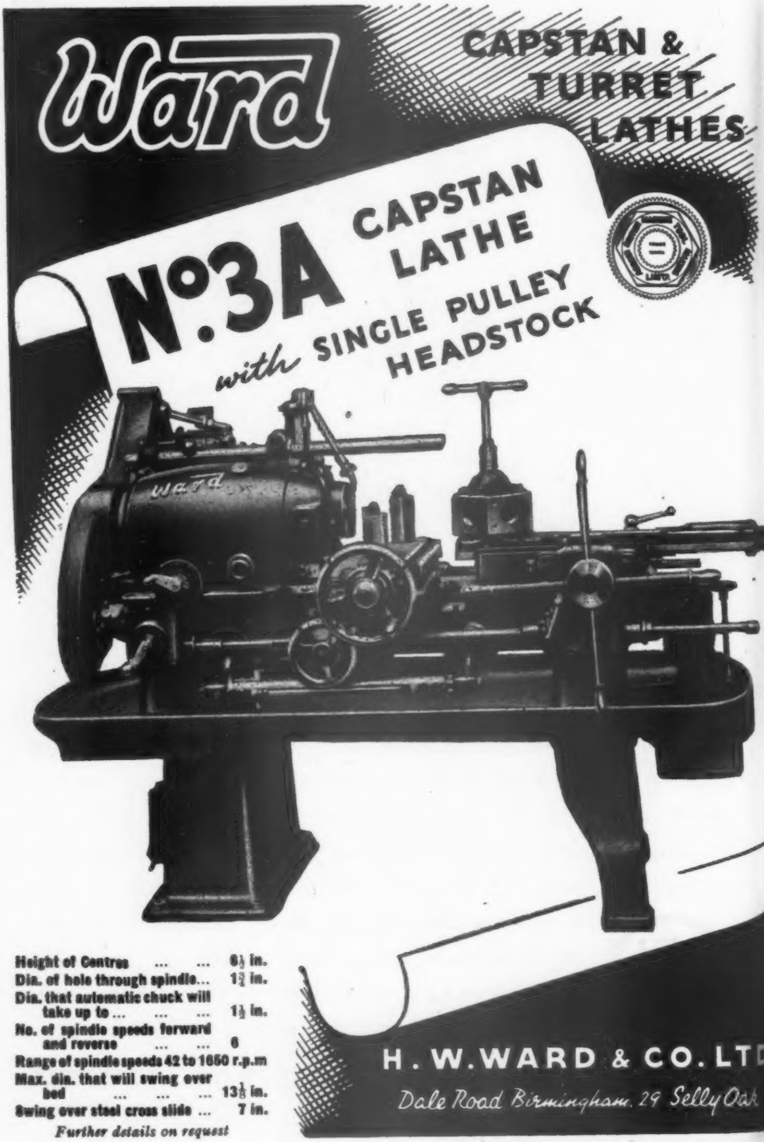

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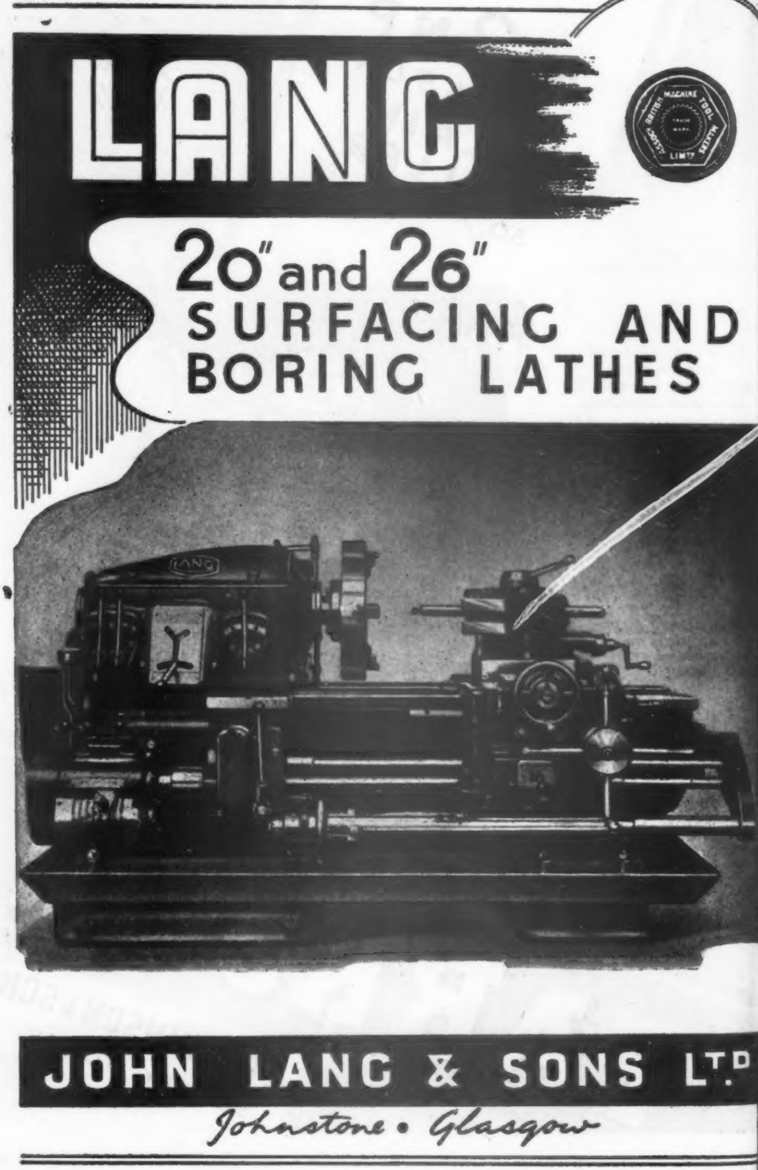
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INSTITUTION NOTES

September, 1946

ANNUAL GENERAL MEETING

Official Notice

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Institution will be held on Friday, 4th October, 1946, at the Institution of Civil Engineers, Great George Street, London, S.W.1, at 2.0 p.m.

AGENDA:

1. Notice convening Meeting.
2. Minutes of Previous Annual General Meeting.
3. Election of Members of Council.
4. Presidential Address.
5. Annual Report of the Council - Research - Balance Sheet.
6. Election of Auditors, 1946-47.
7. Election of Solicitors, 1946-47.
8. Votes of thanks.

BY ORDER OF THE COUNCIL,

C. B. THORNE,

Director-General Secretary

Council Meeting

The next Meeting of Council will be held on Friday, 4th October, 1946, at 11 a.m., at the Institution of Civil Engineers, Great George Street, London, S.W.1.

September Meetings

7th Yorkshire Graduate Section. A Social Evening for members has been arranged, taking the form of tea and a visit to the theatre.

11th Luton and District Section. A meeting will be held at the Central Library, Luton, at 7 p.m., when a film, entitled "Job 99—Pluto," will be shown.

September Meetings—*cont.*

16th Derby Sub-Section. A lecture will be given on "Continuous Gauging of Rolled Material," by a representative of Messrs. Taylor, Taylor & Hobson, Leicester, at the Art School, Green Lane, Derby, at 6-45 p.m.

October Meetings

8th Derby Sub-Section. A lecture will be given by F. G. England, Esq., Works Superintendent, Power Samas Accounting Machines, Ltd., on "Power Samas Accounting Machines," at the Art School, Green Lane, Derby, at 6-45 p.m.

9th Luton and District Section. A lecture will be given by G. H. Parlor, Esq., on "The Rubber Bolster Press and Its Application," at the Central Library, Luton, at 7 p.m.

18th Western Section. A lecture will be given on "Observations and Views on Heavy German Industries," by Dr. H. P. Budgen, M.Sc., M.I.C.E., M.I.Mech.E., at the Grand Hotel, Broad Street, Bristol, 1., at 6.45 p.m.

22nd Wolverhampton Section. An illustrated lecture will be given by J. Loxham, Esq., M.I.Mech.E., M.I.P.E., F.R.S.A., on "The Fundamentals of Fine Measurement," at the Wisemore Schools, Walsall, at 7 p.m.

24th London Section. A lecture will be given by W. H. Tait, Esq., on "Plain Bearing Design and Application," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

September Committee Meetings

— Education Committee, at 10-30 a.m., at the Queen's Hotel, Birmingham.

— Membership Committee, at 12-30 p.m., at the Queen's Hotel, Birmingham.

— Finance and General Purposes Committee, at 2-30 p.m., in the Temporary Committee Room, 36, Portman Square, London, W.1.

The Technical and Publications Committee meets every Wednesday at 5-30 p.m., in the Temporary Committee Room, 36, Portman Square, London, W.1.

Until further notice, meetings of the Finance and General Purposes Committee, the Technical and Publications Committee, and the London Section Committee will be held in the Temporary Committee Room at 36, Portman Square, London, W.1. All correspondence is still to be addressed to No. 10, Seymour Street, London, W.1.

SHREWSBURY SUB-SECTION. On Thursday evening, 11th July, Dr. J. H. Paterson, Managing Director of Arc Manufacturing Co., Ltd., gave a most interesting and informative lecture on "The Principles Involved in Fabrication to Replace Castings."

The lecture was followed by a lively discussion, and was greatly appreciated by those present.

Letters of thanks have been sent to Dr. Paterson and to Mr. A. Moore, Principal of Shrewsbury Technical College.

Graduateship Examination, 1946

The following candidates were successful in the 1946 Graduateship Examination :—

S. H. Fry, B. N. Cooper, J. R. Whitby, T. C. Hugill, A. E. Adcock, R. G. Brown, L. H. Bowles, K. E. J. Fitz, W. B. Pamment, T. Lewins, R. A. Miller, T. E. Allen, G. Giles, R. Parsons, D. H. Seymour, M. J. Vivian, W. J. Sheppard, E. W. Beever, P. R. Shackleford.

Obituary

We deeply regret to announce the death of Mr. James R. T. McLaren, Int.A.M.I.P.E., as the result of fatal injuries received at work. Mr. McLaren held the position of Production Engineer at Messrs. Smith and Wellstood, Bonnybridge, Scotland.

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

Books Received

Metal Working and Heat Treatment Manual, Vol. 1, by F. Johnson, D.Sc. Published by Paul Elek, Ltd., London. Price 17s. 6d. net.

Steel Castings, by Eric N. Simons. Published by Paul Elek, Ltd., London. Price 13s. net.

A book entitled *Machine Tool Research and Development*, which is of interest to makers and users of machine tools and students of production engineering, is now available, price 10s. 6d. (by post 10s. 9d.), from the Production Engineering Research Association of Great Britain, Frederick Street, Loughborough, Leics.

Research Department Abstracts

Will all members please note that the Institution's Research Department was transferred to the Production Engineering Association of Great Britain on July 1st, 1946. Dr. D. F. Galloway, B.Sc., has been appointed Director of the Production Engineering Association of Great Britain.

In consequence of the above transfer, the publication of Abstracts in the Journal will be discontinued as from this issue.

OXY-ACETYLENE WELDING

By F. Clark, M.B.E., M.Inst.W.

Presented at the Coventry Section Welding Conference, April 6th, 1946.

Welding as a method of construction or fabrication offers many advantages to the engineering industry compared with other methods of jointing, but it is not possible to obtain the maximum benefit and economies which accrue from the use of welding, unless due consideration is given to certain essential factors, the chief of which are :—

(1) Weldability of material to be joined.

(2) Correct Design.

(3) Type of joint and preparation of parts to be joined.

(4) Selection of most suitable welding technique.

It is difficult to define the precise or quantitative weldability of a metal or alloy. In general terms, however, one may say that it is the ease with which a metal may be welded by a particular process. It is also necessary to consider the effect of heat upon the parent metal and subsequently the properties of the welded joint.

For example, alloys of the magnesium—copper—aluminium group, such as Duralumin, derive their strength properties from heat treatment and ageing, and although easily welded by the oxy-acetylene process, the heat of welding destroys their age-hardening property to such an extent, that the strength of the weld is little better than of cast aluminium.

From a gas welding point of view, commercially pure aluminium is regarded as a metal of very good weldability ; whereas in the case of spot welding it has a comparatively poor weldability, due to the refractory oxide skin and the fact that aluminium, having high thermal conductivity, requires considerable electric current to produce efficient spot welds and such current may not always be available.

Importance of Design.

Many jobs are "welding failures" due to the fact that they were not designed for welding. Much good welding has been wasted because the design made it impossible for the welded joint to perform satisfactorily the service for which it was intended.

For a designer to take full advantage of the facilities afforded by welding, it is essential for him to have a sound knowledge of the fundamental principles of welding, and, preferably, some practical welding experience. Without such knowledge or experience, he can hardly be expected to appreciate the requirements and limitations of a process, or to visualise the difficulties which a welder may encounter.

In the past there has been a tendency for designers to take a design originally intended for some other method of jointing and merely adapt it for welding, often by the addition of the magical words "weld here." Fortunately, however, this undesirable practice is dying out, largely due, no doubt, to the efforts made during the past few years by government, technical and industrial bodies in organising welding courses, conventions, demonstrations, etc., with the object of making the engineering industry "welding minded."

A successful welded fabrication must be created on the drawing board, and a good welded design should indicate the following advantages over other methods of construction :—

(1) *Weight saving*—a 10-30% saving in weight should be achieved by the elimination of surplus metal, such as bolts or rivets and overlap seams.

(2) *Smooth joints*—the uniform thickness and internal smoothness of a welded joint, particularly a butt joint, is an important factor in the fabrication of chemical, food, heating and refrigerating plant, since it prevents the possibility of corrosive materials becoming entrapped, due to obstruction, at the joint.

(3) *Strength*—the strength of a welded joint should be at least equal to the strength of the materials being joined together. Furthermore, a welded joint should be permanently leak proof.

(4) *Economy*—the overall costs of a welded product should be lower than other methods of construction, due to reduction in weight or material and consequent saving in handling and transport costs, less expensive preparation of parts to be joined and a reduction, it not elimination, of maintenance costs.

The most desirable type of joint, particularly for welding non-ferrous metals, is the butt joint, and when welded in the underhand position, it offers the maximum accessibility to the welder, is faster to execute, and lends itself more readily to jigging, chilling or dressing, and most important of all, the complete removal of flux after welding.

It may be argued that the design of a welded project is less complicated when fillet welds are employed ; whilst this may be true, to

a certain extent, from the designer's point of view, it does not apply so far as the welding is concerned.

Generally speaking, butt welds executed in the underhand position should, wherever possible, be the aim of modern welding design. Such an achievement is not as difficult as might appear at first sight, due to the fact that in recent years considerable progress has been made in the art of producing extruded sections which make provision for butt welds.

Effect of Expansion and Contraction.

The amount by which various metals expand when heated, and contract when cooled, varies considerably from one metal to another and all common non-ferrous metals expand or contract to a greater extent than steel. For example, aluminium expands about twice as much as steel, while a zinc-base alloy has an expansion coefficient of nearly three times that of steel.

It follows, therefore, that due allowance must be made for thermal expansion and subsequent contraction during and after the welding operation.

For sheet metal work, jigs and clamps—often of simple design—can be used to extract heat along the line of weld ; to assist in controlling expansion and contraction of the weld metal and maintain rigidity and alignment of the job. Such devices could be more frequently and advantageously employed than they are, and thus prevent or reduce distortion to a minimum.

The relative amount of distortion due to contraction that is likely to occur with butt, fillet and corner welds, depends to a great extent upon the angle between the fusion faces, since contraction of the weld metal is approximately proportional to the cross section of the weld. There is, therefore, more contraction across the top than at the bottom of the welding vee, hence it is desirable to employ as small a vee as possible.

It will also be obvious that apart from heat spread in the plate, there is a greater tendency to distortion due to contraction of weld metal when using fillet welds compared with butt welds. If, in an attempt to prevent contraction of the weld metal, the part is restricted in such a manner that movement cannot take place, the weld metal will solidify in a stressed condition and fracture of the weld metal, or the metal adjacent to the weld, may occur.

When using jigs therefore, it is advisable to permit some degree of movement of the plate edges towards one another, by having the jig tight enough to maintain alignment and yet permit a certain amount of "creep."

The joining of unequal masses of metal is always an undesirable and difficult operation, even when in the form of a butt weld, owing

to the fact that the smaller section becomes over-heated or melted before the thicker section has attained fusion temperature.

It is desirable that welded joints should be located so that they are subjected only to tension or compression stresses and not to bending or shear stresses. This principle is particularly important in connection with the design of welded pressure vessels of any type.

By substituting semi-elliptical end plates pressed to give a butt weld between the edges of the end plates and the edges of the shell, the weld should be entirely relieved of a bending movement.

Hammering or mechanical rolling is often used as a complete finishing treatment for non-ferrous metals such as magnesium, aluminium or copper, or it may be used as a preliminary to grinding or filing. It eliminates or closes any porosity there may be in the weld, removes buckles and reduces the area or excess thickness at the weld line. A further point in favour of hammering is that it improves the physical characteristics in the weld area of most non-ferrous sheet metals.

A hold-up dolly on one side is essential where the part cannot be placed upon an anvil and provision of access for the dolly must be provided in the design of the product.

It is obvious, of course, that no matter how good a welded design may be, the efforts of the designer will be wasted if the welder himself does not appreciate, not only the problems of design and the requirements of the welded joints he is to make, but also the characteristics of the metal to be welded and that he has the necessary ability to employ the technique most suitable to the work in hand.

Characteristics of Metal to be Welded.

Careful consideration must be given to the following characteristics of metals which are of direct importance before, during and after welding :—

(i) *Melting point.*—With the exception of nickel, the melting points of the non-ferrous metals and alloys are much lower than that of steel, and in many instances there is no visible colour changes before the metal melts. Thus aluminium, magnesium, zinc and lead, together with their alloys are completely molten at temperatures below visible red heat. The welder, therefore, must be careful not to overheat and collapse the metal during welding.

(ii) *Thermal Conductivity.*—Non-ferrous metals in general have considerably greater conductivity than steel. For example, aluminium conducts heat nearly five times, and copper almost nine times, as fast as steel. The heat of welding is thus conducted away from the weld to raise the temperature of the surrounding metal to a far greater extent than in steel,

and it is this factor which controls the size or power or number of blowpipes to be used. In gas welding aluminium and copper it is therefore necessary to preheat the parent metal in order to obtain proper and rapid melting. Stainless steel, however, having a low thermal conductivity and high coefficient of expansion, is therefore subject to considerable distortion during welding, which necessitates rigid control by means of closely spaced tack welds, and a robust type of clamp. Furthermore a smaller size of welding nozzle is required for a given thickness of mild steel.

(iii) *Mechanical Properties.*—Whilst the pure metals are relatively soft and weak, they are strengthened by cold working, such as rolling, drawing, pressing and stamping. Many of the alloys are in the same general category, but are, of course, stronger than the chief metal of the alloy concerned. Steel is a metal which is inherently strong in the cold state and also retains considerable strength when heated even to the plastic state. On the other hand, some metals lose their strength very rapidly when heated, for example, copper has relatively no strength whatever when heated to just below its melting point.

In general, the tensile strength suffers progressive reduction as the temperature is raised, while the ductility increases. In some materials, copper again for example, there may occur ranges of comparatively low ductility or even brittleness within certain temperature ranges. Fig. 1 shows an example of this " hot shortness " in a specimen of arsenical copper. The tensile strength falls fairly uniformly as shown by the curve, but the ductility as measured by the percentage elongation of a 2-in. gauge length, falls rapidly between about 400° and 600°C., after which it increases. Any stresses, due, for example, to constraint, falling on this particular copper might result in the development of cracks if applied when the metal temperature was 600°C. In welding practice, therefore, care must be taken to avoid stressing the metal within such brittle ranges.

The behaviour of a metal when heated thus controls the method or welding procedure to be adopted. For instance, a simple short butt weld in mild steel may be tacked and welded from edge to edge in a continuous run of welding. Such a procedure adopted for welding copper would, however, cause fracture to commence by the time the weld had proceeded for an inch or so and the fracture would follow closely behind the blowpipe. Copper must not be restricted and a procedure to relieve the weld metal while it is solidifying

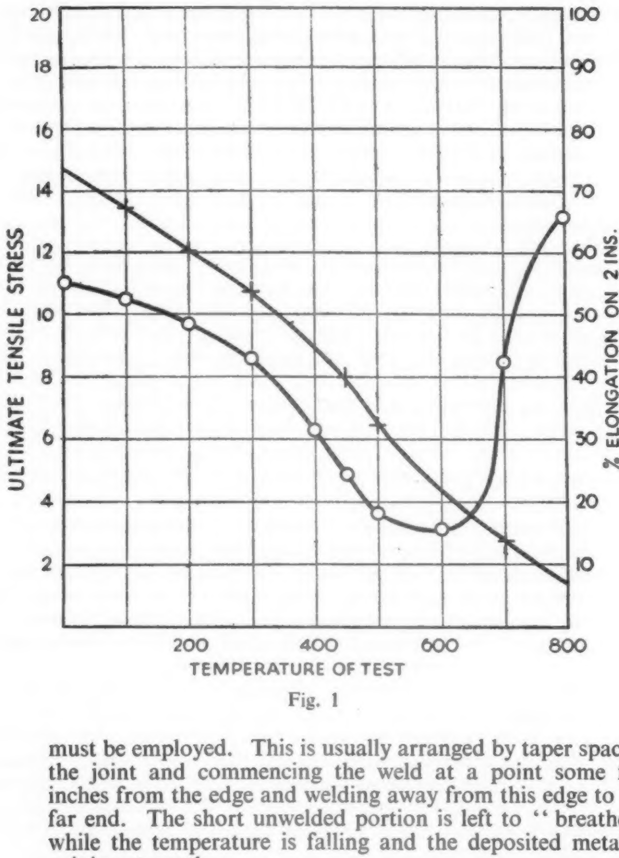


Fig. 1

must be employed. This is usually arranged by taper spacing the joint and commencing the weld at a point some few inches from the edge and welding away from this edge to the far end. The short unwelded portion is left to "breathe" while the temperature is falling and the deposited metal is gaining strength.

In view of the fact that the majority of non-ferrous metals all tend to be "hot short," it is a sound principle to adopt a procedure whereby welding is carried gradually forward with the joint free to move whilst the weld is proceeding.

Flame Adjustment.

Correct flame adjustment for a particular metal will have a considerable bearing upon the properties of a welded joint, and while

the majority of weldable metals require a neutral flame, *i.e.* approximate consumption of equal proportions of oxygen and acetylene from the source of gas supply, there are some metals or special applications which require an oxidizing (excess oxygen) or carburizing (excess acetylene) flame. See Fig. 2.

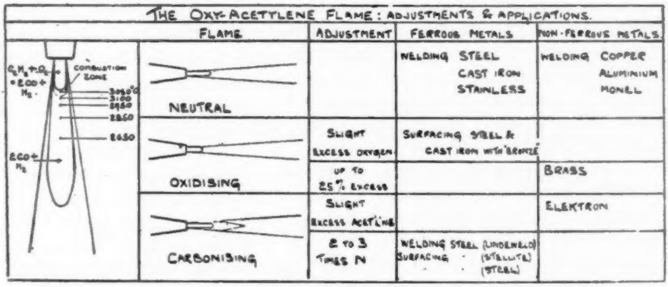


Fig. 2

Stainless steel is greatly influenced by flame adjustment and although a flame having a slight haze or feather of acetylene is recommended, an actual excess of acetylene will alter the characteristics of the weld metal very considerably, making it hard and brittle and which, when polished, will show as a "milky" or white line.

Flame adjustment in welding bronzes and brasses is most important. By using an oxidizing flame, loss of zinc by volatilization is prevented by the formation of a protective coating of zinc-oxide over the weld area, and a satisfactory weld is obtained. A neutral flame causes a porous and brittle weld, due mainly to the volatilization of zinc during welding.

Aluminium, magnesium and their alloys require not only a neutral flame, but one which is described as a "soft" flame to prevent any undue agitation of the molten metal during welding.

Welding Rods.

A wide range of welding rods is available to industry, but since the physical characteristics of these rods may vary very considerably, care must be taken in selecting a welding rod which will reproduce the service requirements of the parent metal. A jointing rod has strength and ductility and the weld metal is usually soft ; a rod for resurfacing or building up worn parts produces a weld which is hard and relatively brittle, each must therefore be used within their respective fields.

There are, however, one or two notable exceptions to this rule ; firstly, a low carbon steel rod containing approximately $3\frac{1}{2}\%$ nickel,

which will give a high tensile strength joint, yet at the same time the weld deposit has a fair degree of resistance to frictional wear; secondly, a rod in the non-ferrous range of the nickel bronze type which produces an extremely strong bond between two pieces of steel or cast iron; while the same rod will produce a weld deposit which is extremely resistant to frictional wear provided the deposit, in service, is kept well lubricated.

The size of rod used is another important feature in welding and is the reason why rods are available in many and varied sizes. The following may be taken as a general guide in selecting the correct size of rod for welding sheet metals :—

Underhand butt joint in sheet up to $\frac{1}{8}$ in. thick, $D = t$

Underhand butt joint in sheet over $\frac{1}{8}$ in. thick, $D = \frac{t}{2}$

Vertical butt joint in sheet over $\frac{3}{8}$ in. thick, $D = \frac{t}{3}$

where D is the diameter of rod and t the thickness of parent metal. In the case of non-ferrous metals it is usual to use a rod rather larger than the material thickness for light gauge metals up to say 14 gauge.

Fluxes and Flux Removal.

Most of the non-ferrous metals oxidize in the air, the rate of oxide formation increasing as the temperature increases.

As oxides are undesirable in the completed weld, protection from oxidation is a primary precaution, but it is not usually possible to prevent oxide formation completely. Any oxide formed must therefore be removed, and for this purpose for non-ferrous welding, a flux is normally employed. The flux either attacks the oxide and dissolves it or floats it away and so removes it from the weld metal in the form of slag. It also protects the metal from oxidation during welding and the slag formed prevents oxidation of the metal during cooling.

Many fluxes are corrosive in action and their complete removal after welding is essential, otherwise the corrosive action will continue indefinitely. It is not sufficient merely to wash-off the part in cold water. The usual recommendation is to scrub the part thoroughly in hot, preferably soapy water, or where possible, to immerse the part completely in boiling water for 15-20 minutes. Where immersion and boiling is not possible, a more positive method of flux removal is to scrub lightly around the weld area with a 5% nitric acid solution, followed by thorough water rinsing. Hot water is preferable as it facilitates drying. The nitric acid solution should be used warm at about 60°C. Magnesium and its alloys should be treated by a method known as "chromating" which is applied after the flux has been removed. This gives the material a protective

coating, so guarding it against atmospheric attack, as well as killing any last traces of flux.

Welding Techniques.

Various welding techniques are available, each having definite advantages and limitations within certain ranges. There has been in the past, and still is, too great a tendency for welders and engineers to use a technique or procedure that has proved satisfactory for steel for the welding of non-ferrous metals ; this has undoubtedly retarded the development of non-ferrous welding and it is essential that welders appreciate the difference not only between the ferrous and non-ferrous metals in general, but also between individual materials.

In addition, specific training for each metal should be undertaken and if an operator is not welding a particular metal regularly, he should always complete a few practice welds before attempting to execute production welds.

A brief reference to the more generally applied techniques is as follows :—

Selection of Welding Technique.

Whereas a few years ago there was only one generally accepted method of welding, during recent years other methods or techniques have been evolved, with a view to increasing the efficiency or lowering the cost of welding. It is probable that many welders to-day have at least a cursory knowledge of some or all of these methods, but often they do not appreciate the advantages and limitations or know when any particular technique should be employed. It is sometimes found that a welder has a good knowledge and ability of a particular technique, but is using it beyond its useful or economical scope.

On the other hand, one may find a welder who has acquired only a very elementary knowledge of a particular technique and has not mastered all the points correctly, with the result that the technique is inefficiently applied.

These things, of course, bring distrust upon the claims put forward for any particular welding method and often result in faulty welds, due entirely to the inefficient application of the technique being used.

Experience has, however, shown that a very wide range of control can be exercised over the many factors influencing a satisfactory weld by the utilisation of the correct welding technique, providing the welder has acquired sufficient knowledge and ability for correct application.

The oldest and most generally known technique is termed the "Leftward" or "Forward" method ; but the more recently developed techniques such as rightward welding, vertical welding,

with one or two operators and variations of one or two of these methods, have greatly improved the quality of the deposited weld metal, the efficiency of the gas welding process, increased the speed of welding and reduced the overall costs.

Leftward Welding.

This method is often employed well beyond its efficient range, due no doubt to the fact that it is the oldest, and most generally accepted technique throughout the welding industry. Its most effective utilization, however, in connection with rolled sheet or plate, is for thicknesses up to and including $\frac{3}{16}$ in., when welding is carried out in the underhand position.

For butt welds on steel up to $\frac{1}{8}$ in. thickness no preparation of the edges is required beyond the arrangement of a satisfactory gap. Good fused penetration is relatively easy to obtain. Above this thickness, however, it is customary to prepare the plate edges to a bevel, to give an included angle of 80° or 90°.

Such a welding vee necessitates a considerable amount of weld metal and it will be appreciated that the greater the thickness range, the greater will be the difficulty of filling the vee in one run and at the same time obtaining satisfactory penetration. If a procedure involving super-imposed runs is employed, then cost is considerably increased due to wastage of gases and time, while distortion caused by the width of weld metal shrinkage will be considerable. Notwithstanding this, however, it is usual to employ the leftward method for the repair of cast metals such as cast iron, cast aluminium or cast elektron, whatever their thickness. This is mainly because the

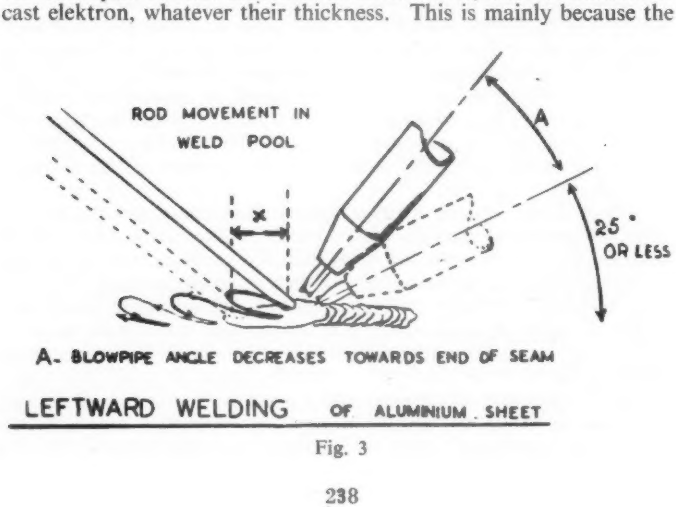


Fig. 3

casting is preheated before welding and there is, therefore, not the amount of heat-loss from the blowpipe and also because owing to the greater fluidity of these cast metals, better control of the molten metal is obtained by welding in short super-imposed runs.

With a right-hand operator the direction of welding is from the right to the left and the blowpipe flame is played on to the unwelded edges. The forward heat of the flame precludes the adoption of a smaller vee than 80° due to the tendency of the flame to melt the top edges and to push molten metal forward over unmelted surfaces, resulting in a state of adhesion along the seam. The width of the vee and the large amount of weld metal involved also limits the welder's ability to retain control over the large molten bath.

For plate thickness over $\frac{1}{4}$ in. the welder also finds it necessary to impart to the blowpipe a swinging motion in order to heat and melt the sides of the vee adequately. This movement of the blowpipe increases the area being heated with a corresponding increase of gas consumption and distortion. The limiting thickness of $\frac{3}{16}$ in. for leftward welding is based on extensive examination of the results of practical work, whilst it has been found that up to the $\frac{3}{16}$ in. thickness for underhand welding, the speed, general economy and quality of the weld is equal to or better than that of any other technique.

Fig. 3 gives a general indication of the blowpipe and rod angles for leftward welding, but more particularly indicates the gradual lowering of the blowpipe angle which is usual when welding aluminium sheet.

In certain instances where unsatisfactory welds have resulted, a slight variation of the leftward method has been developed. There is one particular grade of light gauge steel sheet which tends to blister or coke on the underside when welded and the procedure known as a modified leftward technique is often employed.

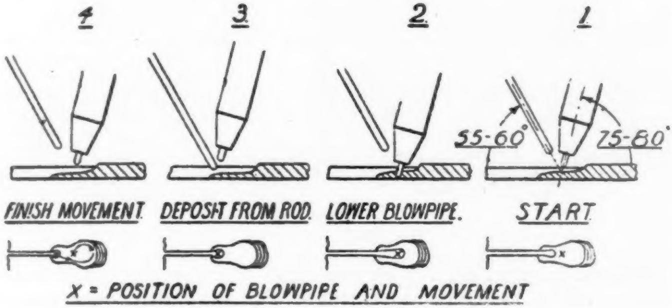


Fig. 4

Fig. 4 shows the welder's view of this technique. The angles at which the rod and blowpipe are held are steeper and there is an occasional lowering of the flame towards the weld pool, with a short flick or circular movement of the flame. A small hole is produced and maintained and this cycle is repeated as the weld proceeds. This hole, together with a pre-arranged gap equivalent to half the metal thickness, allows a part of the flame envelope to percolate and prevents immediate atmospheric attack on the hot metal on the underside of the weld. A welder of average ability should be able to master this modification with a little practice and produce welds of much better quality with it.

Rightward Welding.

In order to overcome the difficulties experienced with the leftward method of welding on plate thicknesses over $\frac{3}{16}$ in. the backward or righthand technique was developed. The chief difference between leftward and rightward welding lies in the control of the molten metal. Whereas leftward tends to force forward the molten metal on to the unfused edges, by the rightward method the weld metal is largely controlled by the up lifting force of the flame and the movement of the filler rod which results in single pass welds being

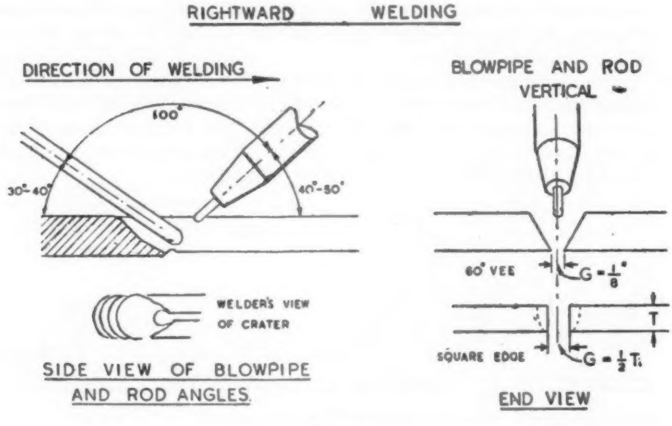


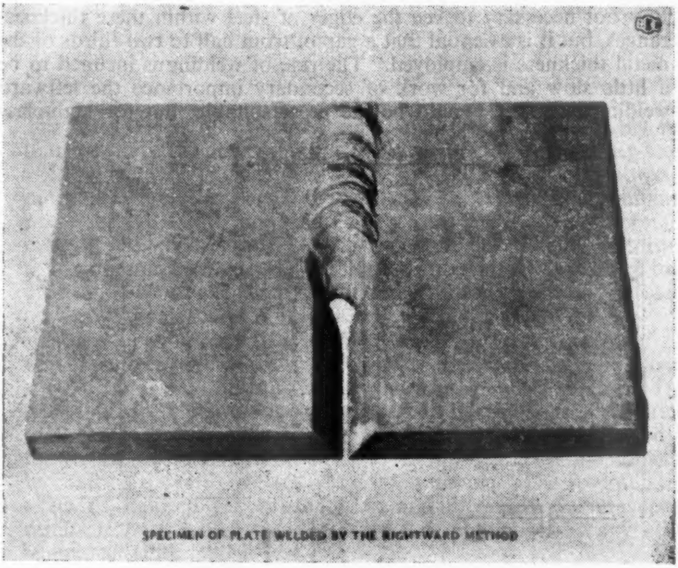
Fig. 5

achieved on plate up to $\frac{5}{8}$ in. thickness. Furthermore, there is not any need for blowpipe movement so that the heat is concentrated within the vee faces. The welding wire is melted in front of the flame

against a background of deposited weld metal much more rapidly and thus achieves a higher welding speed. This reduces gas consumption per unit length, although a higher powered blowpipe can be used, and so reduces the overall costs for any given footage of welding. Other advantages are :—

Plate thicknesses up to $\frac{5}{16}$ in. can be welded without vee preparation on the edges, thus eliminating the cost of bevelling. For plate thicknesses above $\frac{5}{16}$ in., the vee, which is employed, need not exceed an included angle of 60°, consequently a smaller amount of filler rod is required. See Fig. 5. Completely fused penetration is ensured by the direction of the flame and weld metal is controlled by rod movement and power of blowpipe. The welder has an unobstructed view of the weld metal pool, while the characteristic of good rightward welding is the uniform bead of weld metal formed by the penetration which to the welder has the appearance of a small hole caused by the fusion of the bottom edges of the vee. A uniform gap of approximately $\frac{1}{8}$ in. is essential. Fig. 6 is a view of a perfectly executed weld in $\frac{3}{8}$ in. mild steel plate.

This technique is particularly efficient for steel within the ranges



SPECIMEN OF PLATE WELDED BY THE RIGHTWARD METHOD

Fig. 6

given. Rightward welding is rarely employed on non-ferrous metals or cast iron. It is owing to heat concentration at the point of welding and difficulty of maintaining control over the very fluid weld pool, that this technique is not so suitable for low melting point metals. Although the control obtained by rightward welding not only in the underhand position but also in the vertical and overhead positions is greater than with leftward welding, it is nevertheless a difficult technique to master, particularly in connection with varying surface angles as in pipe welding.

Vertical Welding.

There are, of course, many classes of work where it is possible to weld in the underhand position only, but there are times when work can be arranged in such a manner that the joint is in the vertical position. For materials below $\frac{3}{16}$ in. and where one side of the joint only is accessible, the single operator vertical welding technique can be employed with advantage. This method has sometimes been described as the "hole in the wall" method. As this name implies, welding produces a small hole at the front of the weld crater. This ensures perfect penetration with a very sound weld. It is not necessary to vee the edges of steel within these thickness ranges, but it is essential that a gap of from half to two-thirds of the metal thickness is employed. The rate of welding is inclined to be a little slow and for work of secondary importance the leftward welding technique would be the most suitable, but for high-class

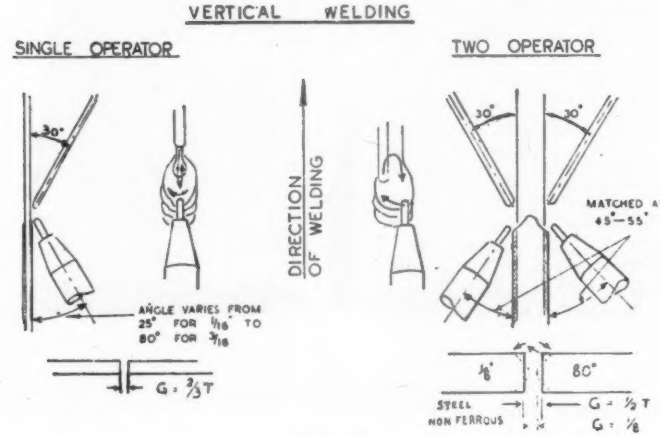


Fig. 7

work such as small light gauge steel pressure vessels or tanks, the single operator vertical technique is the most suitable to employ.

On thicknesses of plate above $\frac{3}{16}$ in. where both sides of the joint are accessible and it can be arranged in the vertical position, the method of employing two operators working simultaneously has much to commend it. This method, known as the Two-operator Upward Vertical Welding Technique, offers many advantages.

Steel plates from $\frac{3}{16}$ in. to $\frac{5}{8}$ in. thick can be welded without bevelling the edges of the plate, oxygen cut or even rolled edges are suitable, thereby eliminating the cost of veeing and decreasing very considerably the consumption of filler rod. A gap equal to half the metal thickness with a maximum of $\frac{1}{4}$ in. is essential, however, to ensure complete fusion throughout the thickness. See Fig. 7.

Aluminium and copper in various thicknesses can also be welded most satisfactorily in this way although in the case of these metals it is usual to double bevel material of $\frac{3}{8}$ in. thicknesses and greater. Bevels should give an included angle of 70° to 80° on either side of the plate and there should be a small flat or nose at the centre of the join of approximately $\frac{1}{8}$ in. Without this nose, control of the metal is difficult and a feather edge melts back and produces an unnecessarily large " hole " in the centre of the weld crater, causing excess metal to spill down the welded portion.

Non-ferrous metals particularly demand the careful matching of blowpipe flames and co-operation and team work from the two operators, to prevent excess metal being forced through the gap. The total power of both blowpipes employed is considerably less than would be the power of a single blowpipe used on an under-hand weld on metal of similar thickness, in fact, the reduction of blowpipe power for the thicker ranges of metal may be such that the combined power of both blowpipes does not exceed 60% of that normally used for underhand welding. This technique reduces plate distortion to a minimum owing to the application of an equal amount of heat on both sides of the plate simultaneously, together with the same amount of contraction of weld metal and uniform cooling.

Consequent upon the use of smaller blowpipes, control of the fluid metal is very much easier, due to the fact that a relatively small pool of fluid metal is carried upward by each operator. This technique, therefore, is admirably suited for the welding of cylindrical tanks and vessels where the longitudinal seam can be arranged in the vertical position, and the circumferential seams can be completed by rotating the tank when it is laid upon its side. The accumulative effect of reduced gas consumption and increased welding speed results in an overall lower cost than that obtainable by any other technique within its efficient scope.

This technique is not, however, limited to new fabrication plate work in the form of vessels and drums, but has been used success-

fully on such work as steam piping and cast iron bronze welded repairs.

For the fabrication of steam heating units where a large number of smaller pipes are introduced into a cross pipe or header in the form of branches, the use of two operators working simultaneously will almost entirely eliminate distortion or side bowing of the cross pipe in addition to which the welds are completed more effectively and quickly owing to the greater utilisation of heat input.

In the same way, heavy cast iron sections bronze welded simultaneously from both sides, remain relatively true and do not tend to " pull " or " bird wing " as occurs when welds are made from one side only. Again, the speed of welding is considerably increased and the total amount of heat put into the job is kept at a minimum, which in turn means less possibility of distortion in other parts of

Fig. 8

Fig. 9

the castings. Figs. 8 and 9 show various views of the repair of a heavy cast iron evaporator by this method, the fractured joints being arranged in an approximately vertical position by turning the casting around as the weld proceeded. Welding was undertaken in short stages of 4 in. to 6 in. at a time and the deposit then lightly hammered to stretch the bronze weld metal. Preheating which is necessary for bronze welding, although it may be to a relatively low temperature, was in this instance carried out by coal gas bunsen burners. The large body of the evaporator was preheated prior to welding the fractured side, by the additional use of electric heaters stood inside throughout the night. The fractured door and body each of $1\frac{3}{8}$ in. section with $1\frac{1}{2}$ in. stiffener webs were completed in 11 hours actual welding time, and the evaporator afterwards tested to 20 lbs. per sq. in. water pressure for one hour, in the presence of a boiler insurance company's inspector and found to be satisfactory.

Importance of Correct Preparation.

Whereas with a joining process, such as riveting, the sizes of the holes, the distance between them and the distance from the edge of the plate, all have to be carefully watched if an efficient riveted joint

is to be obtained, considerable carelessness is frequently displayed in preparing edges for welding. In the case of upturned or flanged sheet metal edges, the flanges must be uniform in height otherwise irregularity would cause a varying welding speed and at some places, excessive flanging would cause adhesion and a heavy weld bead. Similarly when edges are bevelled, the bevel must be uniform in depth or angle throughout the length of weld. If not, the quantities of weld metal to be deposited to fill the vee will vary to such an extent that heat input and shrinkage varying also, will cause unequal buckling and distortion to the extent that these troubles will be greatly exaggerated. The preparation of the edges or the degree of angle is dependent upon the type of metal to be welded, its thickness and the technique to be employed. The technique itself will be controlled very largely by the thickness. If the vee is unnecessarily large, weld metal will be wasted, gas consumption and welder's time will be increased. On the other hand, if the vee is too small, difficulty will be experienced in achieving full fusion throughout the thickness of the metal. Weld quality will therefore suffer.

In principle it can generally be assumed that the vee should be as small as possible for the technique selected for it to be consistent with obtaining full fusion and penetration throughout the thickness of the base metal. A small vee also has the advantage that weld metal shrinkage is reduced as much as possible. This is one of the advantages of rightward welding with its small vee, over leftward welding with its larger vee, and the advantage is still more apparent with two operator vertical welding with square edges and is a reason why square edge welding should be employed so far as it is economical and efficient to do so.

Apart from correct edge preparation, alignment and spacing of the edges are very important if full penetration is to be obtained. Here again it can be taken as a general guiding principle that the larger the vee, the smaller the space required between the bottom edges. For this reason, rightward welding necessitates a slightly greater space between the bevels than does leftward welding, and square edge welding necessitates a still greater space than any type of vee welding. Alignment of surfaces is usually maintained by either employing tack welds or some type of clamping device.

Clamps of the tongue and grooved variety are sometimes employed upon relatively thick steel place work but there is always the tendency for the clamps to be seized should the gap become smaller by the edges approaching the clamp. Difficulty is then experienced in removing the clamps. There are times, however, when considerable pressure is necessary to pull edges into alignment and it is sometimes desirable to drill a hole or holes near the weld line for the insertion of bolts to operate straps. When this is done, the drilled hole is, of course, filled by welding after the weld is completed

or when it has passed this particular point. This procedure is not, however, generally recommended.

Jointing of Dissimilar Metals.

The expression "Jointing of dissimilar metals" or joining by dissimilar metals, covers a very wide field, and one which is very well known and established. So far as copper pipe work is concerned, it is commonly termed "Bronze welding," and is used by the plumbing industry for the installation of domestic services and sanitary installation and by engineering concerns and shipbuilders, etc.

The bronze welding and brazing of Steel to Cast Iron, Brass to Copper or Brass to Steel is also everyday practice. Another application which gives very successful results is the building up of various worn steel parts with Manganese Bronze or Nickel Bronze deposits.

Various types of bronze rods are available. Each have their specific uses and advantages and the type of rod recommended for any particular application should always be used.

The jointing of such dissimilar metals as Steel to Aluminium or Copper or Brass to Aluminium is, however, something new, but to-day can be accomplished easily. To obtain a good joint between

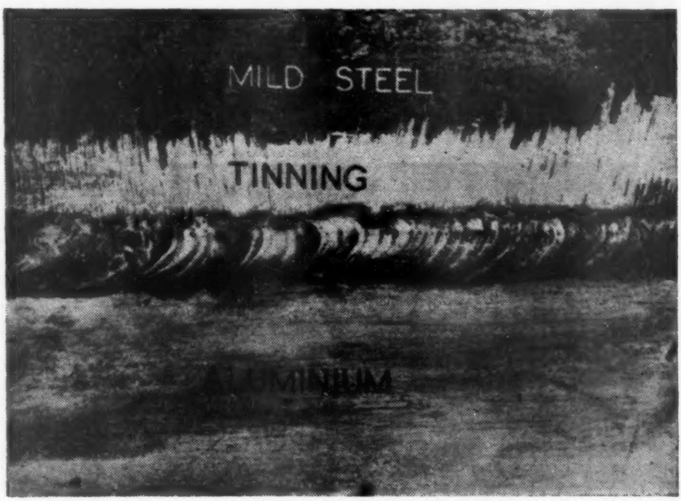


Fig. 10

these metals is a relatively simple operation and undertaken correctly, joints with the strength of 4 to 4½ tons/sq. inch appear to be readily obtainable. See Fig. 10.

The procedure is first to clean mechanically the Steel or Copper side of the joint and then to " tin " its surface, in the same manner as is employed for ordinary soldering. The joint is then made in the form of half-fusion—half-brazing.

An aluminium rod containing about 5% Silicon is normally used. The blowpipe is applied in the conventional manner, but the heat is carefully controlled to prevent overheating of the tin so that the filler rod adheres to the " tinned " side of the joint but fuses with the aluminium side of the joint. A strictly neutral flame is employed and standard aluminium welding flux is used.

This process is already meeting certain demands in industry,

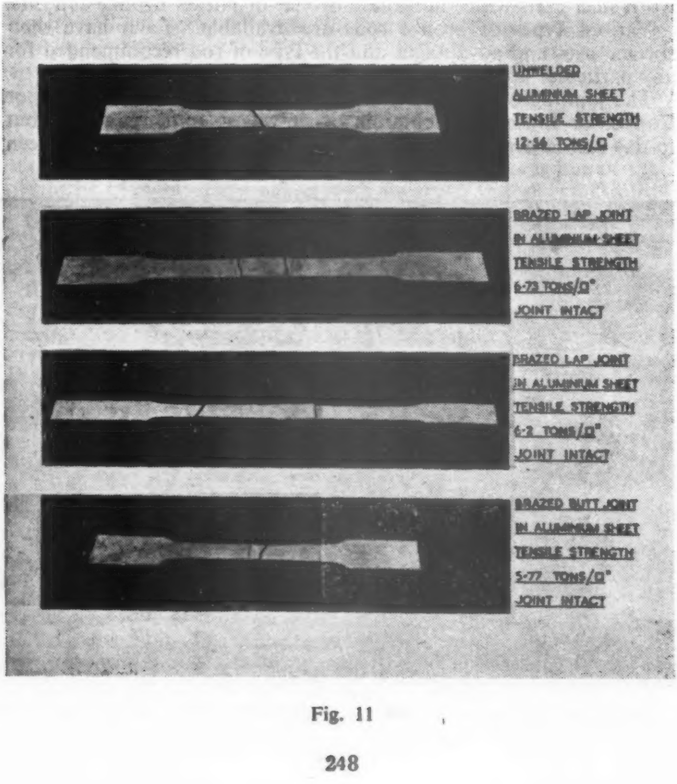


Fig. 11

particularly in the electrical field, where the jointing of aluminium busbar plates to steel sections is demanded.

Brazing of Aluminium.

Light gauge aluminium sheet fabrications have been presenting difficulties in the form of narrow edge fillet or lap joints, where it is frequently difficult, if not impossible, to maintain the sheet contour by fusion welding. This difficulty can be largely overcome by brazing the parts with a rod containing a fairly high percentage of Silicon. The incorporation of 10-12% Silicon produces a rod which has a much lower melting point and has a higher tensile strength, while the Silicon tends to reduce "hot short" cracking.

The brazing procedure which is carried out with standard welding equipment is really a variation of welding practice. A neutral flame is employed, but it is essential that the flux used is finely granulated and has a melting point lower than the rod itself. Some standard welding fluxes are suitable, but others will be found to be too coarsely granular and too high in melting point.

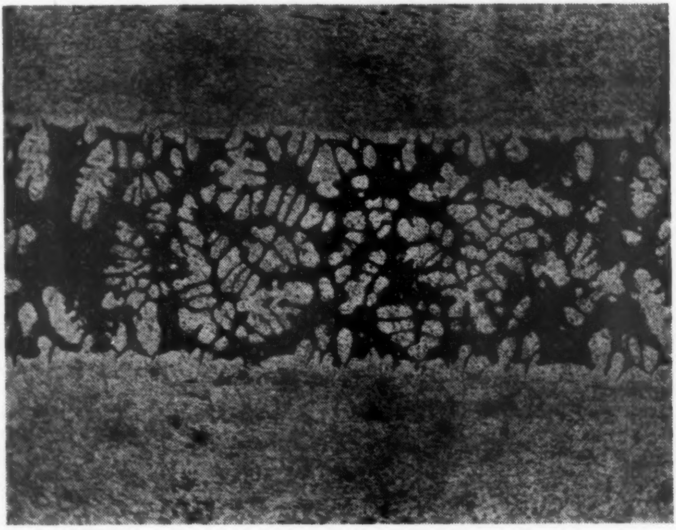


Fig. 12

Parent Material.

Brazing has been employed on commercially pure aluminium to such specifications as L.4-L.16 and L.17, and to a lesser extent on some types of alloy. The greatest difficulty is experienced with brazing alloys containing magnesium. It can generally be said that the magnesium content should be preferably below 2%. Alloys of the Aluminium-Manganese-Magnesium type and Aluminium-Manganese, within specifications DTD 346 and 213A, can be brazed fairly satisfactorily.

Strength of the Joint.

Tensile specimens of both lap and plain butt joints in 16 gauge commercially pure aluminium sheet have been examined and very good results obtained. Fracture has occurred away from the joint

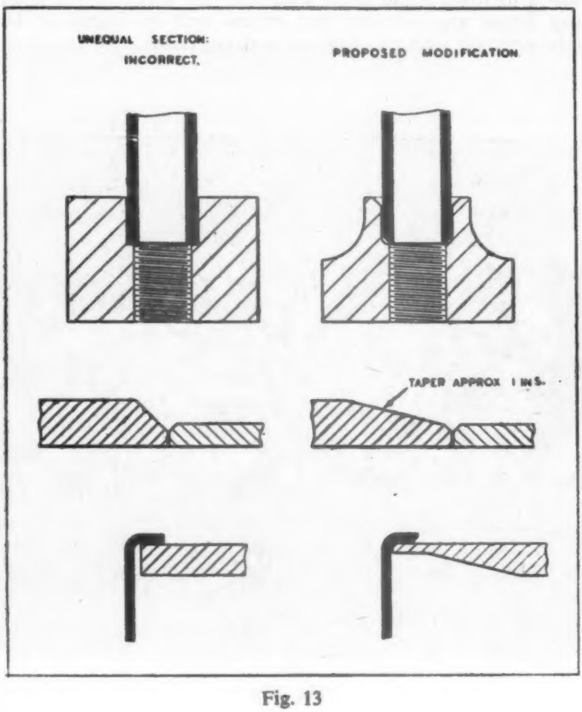


Fig. 13

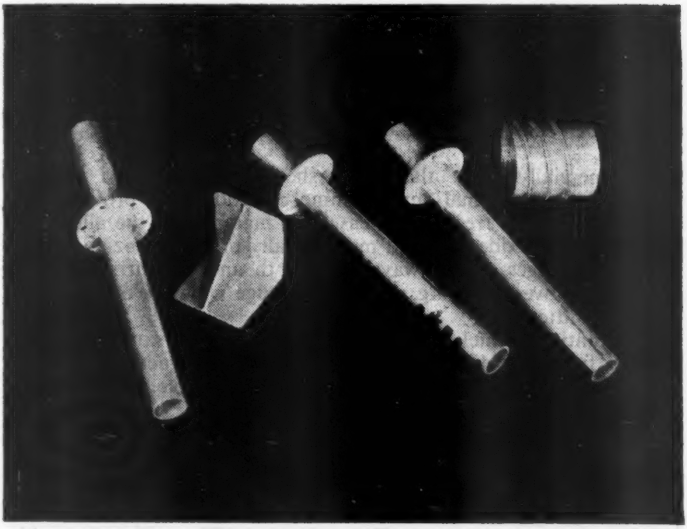


Fig. 14

itself, at tensile strengths varying between 5·77 and 6·73 tons. See Fig. 11. The melting point of the 10-12% Silicon Aluminium alloy is 585°C. and this gives a temperature range or latitude of 73°C. between the rod and commercially pure aluminium sheet. Micrographs with a magnification of 50 and 100 show that the structure of the joint metal consists of primary aluminium rich dendrites in a matrix of aluminium-silicon-eutectic. See Fig. 12. The bond between the rolled Aluminium sheets and the joint metal is perfect.

Fuel Gas.

Various fuel gases are available, such as Hydrogen, Coal-gas, Butane, Propane, and Acetylene. The former produce flame temperatures of the lower order of commercially used gas combinations, but heat spread is fairly wide and tends to add to the operator's difficulty of maintaining small upstanding edges. Oxy-acetylene is preferable because the operator can concentrate his attention upon the flow of the filler metal without having to divide it between this and other parts of the structure.

Preparation.

Press fits and very close tolerances are not recommended. Slight

clearances of the order of 5 to 15 thous. are desirable and in the case of socket joints, the inserted portion should not be more than $\frac{1}{2}$ in. Complete percolation of the filler metal can be obtained through lap joints up to 2 in. wide, but again a preferable width is $\frac{1}{2}$ in. or less. A slight bevel or lead is desirable for all types of work, although in some instances a complete taper of 5° to 10° is recommended.

Commercially pure aluminium sheet can be brazed without removal of the normal surface shine or oxide film, provided the sheet is clean and free from grease, but materials of the alloy type must have the oxide removed mechanically prior to brazing.

Material edges must always be smooth and all burrs and projections removed by filing. A sheared edge which is often burred needs this attention.

The jointing of thick to thin material produces the same difficulties as does fusion welding, and it is recommended practice to reduce joint edges to equality of section wherever possible. See Fig. 13. Figs. 14 and 15 show simple fabrication.

The Argonarc Welding Process.

The Argonarc welding process was developed to meet the need

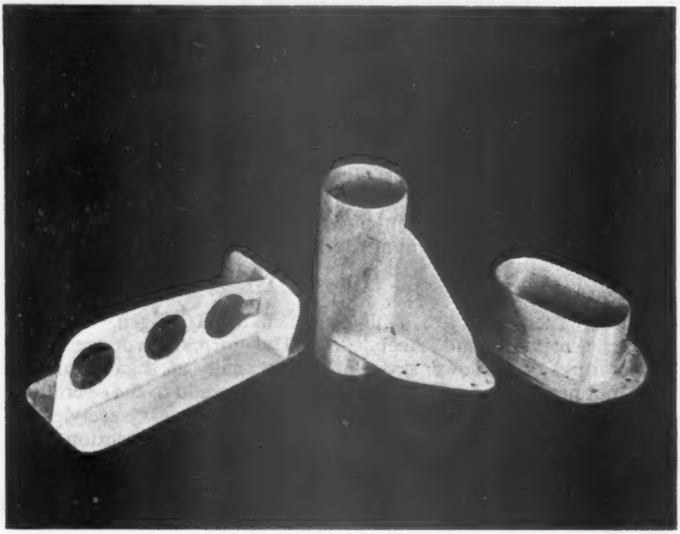


Fig. 15

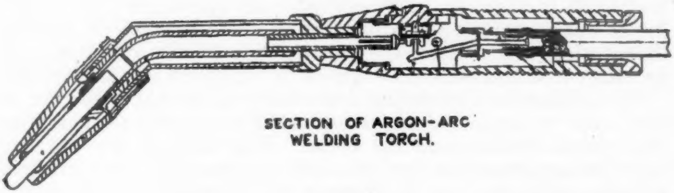


Fig. 16

Fig. 17

that welds in magnesium alloys should not be subject to corrosion by the fluxes commonly used with established processes for welding these metals, and that the somewhat elaborate post-weld treatment necessary to mitigate corrosive attack by the flux should be avoided.

The development proceeded from the premise that if the use of flux could be eliminated and a method of preventing the action of atmospheric elements on the molten metal devised, the problem would be capable of solution, provided that a heat source of sufficient intensity could be used to disperse the superficial oxide on the material to be welded. This process possesses all of these features, since the heat source is a metallic arc operated in an inert gas which fully shrouds and protects the weld area from contamination. The arc is caused to take place between a Tungsten electrode and the

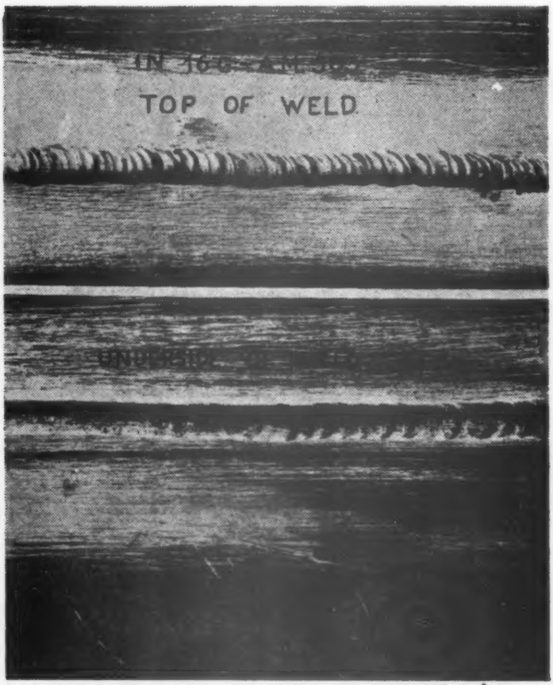


Fig. 18

work to be welded, the electrode being mounted centrally in a nozzle-shaped hood or cup, through which Argon is passed.

As in gas welding, the filler rod is added to the molten material separately, the electrode being used only to provide an arc and since Tungsten has a very high melting point (approximately 3,500°C.) little or no loss of Tungsten occurs.

As its name implies, the Argonarc Process utilizes Argon gas as an inert gas shield and any standard type of electric welding set can be used, the current values of which are similar to those used for light and medium welded work on steel, and both A.C. and D.C. current can be employed.

The inert gas is supplied from a high pressure cylinder, the most suitable containing approximately 100 cubic feet of Argon at 120 atmospheres. For welding, the pressures vary from approximately $\frac{1}{2}$ to 10 lbs. per square inch, and a suitable pressure reducing regulator is supplied with flowmeter attached, to enable the operator to adjust the gas flow to the required conditions. The rate of flow of gas is controlled by a valve at the head of the regulator, but a separate remote control valve is also situated in the handle of the torch. The cable carrying the welding current and the tube carrying the Argon gas are both brought to a common connector, which is attached to a compound cable and gas tube from the welding torch. This compound cable has a rubber tube running through a flexible plaited copper cable and it carries both welding current and gas.

The torch comprises two parts ; the handle or holder to which the compound cable is attached, and the head which carries the electrode and the Argon cup, or hood. See Fig. 16. Two heads are supplied to each complete torch, one for light and the other for heavy work. For light gauge sheet metal welding up to approximately $\frac{5}{32}$ in. thick plate, the small head should be used, but for heavy plate and for large castings where heavy currents are to be used, the large head is the more suitable. Five sizes of electrode have been found sufficient to cover the welding of all types of work, and the sizes of electrodes provided with standard equipment are :—

$\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in. and $\frac{5}{16}$ in.

The equipment necessary for Argonarc welding is summarized as follows :—

(1) Welding generator or transformer.
(2) High Frequency electronic unit.
(3) Torch, complete with electrode holder, electrode and Argon cup.
(4) Cylinder of Argon gas.
(5) Pressure reducing regulator, with flowmeter.
(6) Cable and gas connections.

Accessories are :—

(1) Wire brush or wire wool for cleaning plate and filler rod.

(2) Gloves.

(3) Spare electrodes and electrode holders.

Fig. 17 shows an operator using the Argonarc torch and Fig. 18 is a view of the top and underside of a weld in 16 gauge A.M.503 sheet.

Flame Cleaning of Steel Structures.

The preservation of iron and steel against corrosive attack by the atmospheric or service conditions has been of considerable concern to structural engineers, naval architects and others concerned with the fabrication and maintenance of bridges, ships, storage tanks, railway equipment, industrial machinery, flood gates, blast furnaces, steel works' plant, etc. The importance of proper cleaning is emphasized in B.S.S. No. 1160, which states that it is imperative that the surfaces of iron and steel are properly prepared before painting, that this is a most important factor in determining the life of the protective coating and further that surfaces must be dry before being painted. The beneficial effects of painting on a clean,

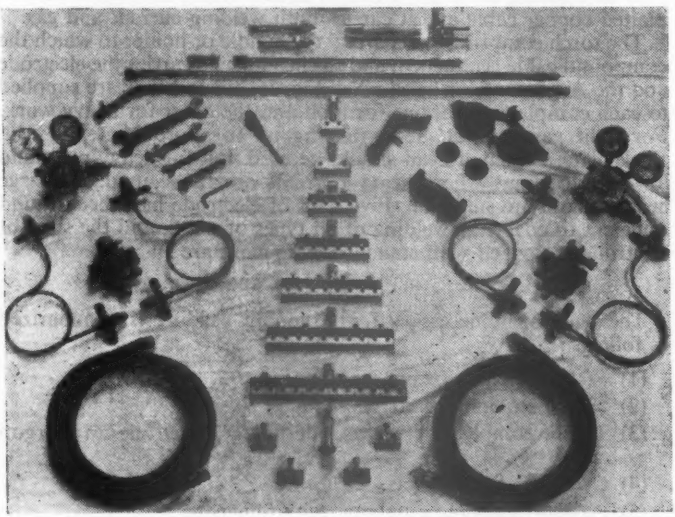


Fig. 19

dry warm surface have long been realized, but it was not until the introduction of oxy-acetylene flame cleaning, dehydrating and descaling, that all three conditions could be achieved.

The flame cleaning process prepares surfaces for painting by "scrubbing" the surface with high velocity and high temperature flames. It removes all unbonded scale and foreign material, drives out occluded moisture beneath the surface scale and removes annealing scale and other similar accumulations from the surface of iron and steel. The temperature of the flame causes a sudden thermal expansion of the particles not tightly bonded to the base metal. This differential expansion may take place within the scale itself, between the top and bottom layers and it causes the scale to pop or fly off. The surface, after being wire-brushed to remove loosened scale, disintegrated rust and other matter, is left in a clean

Fig. 20

warm condition, conducive to the adherence of the priming paint which is applied while the steel is still warm at a temperature of 100°-150°F. and before recondensation takes place. This procedure provides an inactive and protected surface and it improves the corrosion resistance of the paint coating. It increases cleaning and painting rates and reduces setting time for the paint. Painting can be carried out under conditions of dampness which would otherwise cause major delays. The time saved by the flame cleaning process is of particular importance when continuous production is required. The process is sometimes termed flame priming.

Fuel Gas.

The result of comparative tests using different fuel gases has shown that :—

(*a*) *Acetylene* is the only fuel gas which fulfils the requirements given above and the oxy-acetylene flame is the most intense and effective flame for flame cleaning.

(*b*) *Hydrogen* supported by oxygen is not as fast or effective as oxy-acetylene and has the disadvantage that water vapour, produced by combustion, condenses on the cool steel.

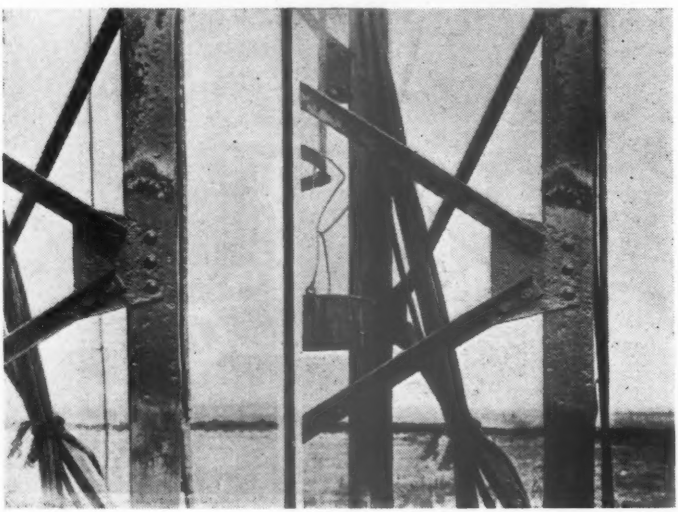


Fig. 21

(*c*) *Propane*. The oxy-propane flame is slow in operation, due to its lower flame temperature, and does not give that almost instantaneous conduction of heat through the layers of scale without overheating the steel beneath, thus minimizing the effect of differential expansion.

Fig. 19 illustrates the equipment used. Some examples of application are shown in Figs. 20, 21, 22.

Oxy-Acetylene Flame Gouging.

Flame gouging provides a means of quickly and accurately removing a narrow strip of surface metal from steel plate, forgings and castings, but differs from the flame cutting process in that the cutting action does not progress throughout the thickness of the metal. It was originally developed for removing metal from the underside of welds and for removing weld defects revealed visually or by X-ray. Due to its success in this field, it has rapidly extended to a variety of other operations, such as the elimination of tack welds, removal of cracks from armour plate, forgings and castings, the preparation of plate edges for welding (see Fig. 23) and for many maintenance and scrapping operations ; in fact, wherever

Fig. 22

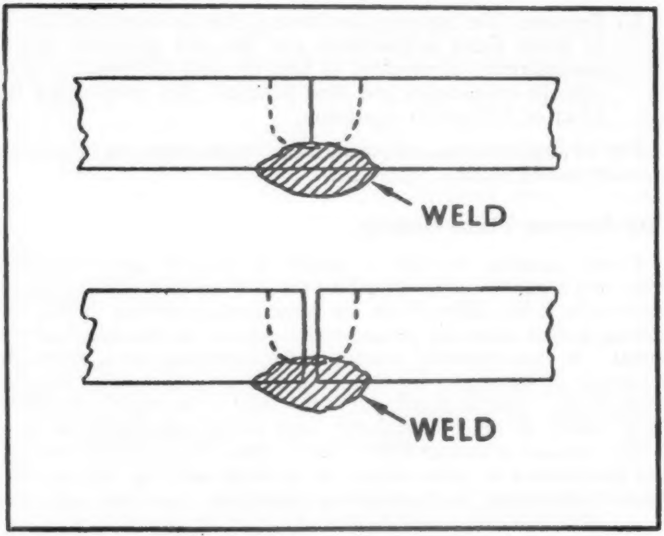


Fig. 23 THE DOTTED LINES INDICATE METAL REMOVED BY GOUGING IN THE PREPARATION OF BUTTED PLATE EDGES FOR WELDING.

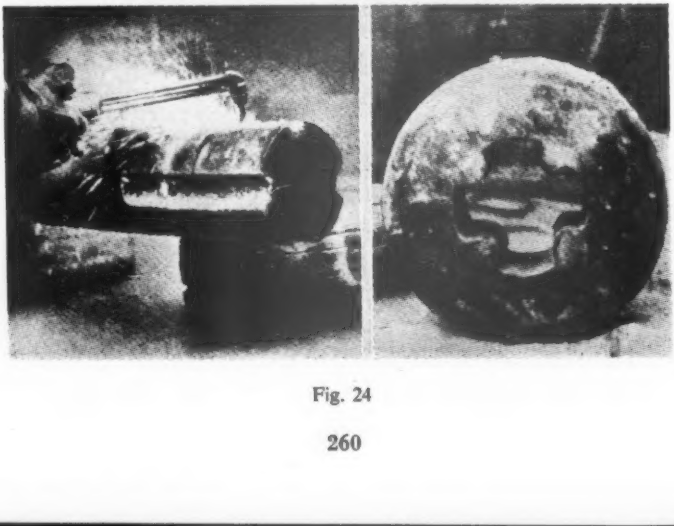


Fig. 24

pneumatic chipping has been used, flame gouging can be employed more efficiently, saving both time and labour. It depends upon the fundamental principle governing all oxygen cutting processes, viz. that if iron and steel are previously heated to a high enough temperature, known as the ignition temperature, it will burn or oxidize vigorously when in contact with oxygen.

The success of the process depends upon the design of a special nozzle, to deliver a relatively large volume of oxygen at low jet velocity. (See Fig. 24.) This, coupled with proper preheat flame distribution and correct manipulation of the gouging blowpipe, will enable a smooth accurately defined groove to be produced in the surface of the steel plate. By using different sized nozzles and manipulations the groove can be varied in width and depth as desired. The speed of operation is at least three times that of chipping while the finish is vastly superior.

One of the major applications of flame gouging is in the removal of the underside of welds where sealing runs are required on high class work such as pressure vessels. For the fabrication of tanks of butt welded construction, it is frequently specified that the root of the initial weld be removed before the sealing or back weld is made. When gouging cracks, the operator can quickly and accurately remove the areas of metal as the cracks tend to show as a white hair line. The advantage over chipping is apparent here because chipping has a tendency to smear over crack defects.

Assembly lugs and cleats used in welded fabrication frequently leave ugly scars on the work after removal by chipping or hammer blows but flame gouging removes such obstructions and tack welds flush with the parent plate, leaving a clean smooth surface.

For plate preparation, it is a speedy and economical method of trimming abutted edges. When the plates are positioned, the gouging blowpipe produces a groove by removing the edge of both plates simultaneously. A large amount of slag tends to adhere to the sides of the groove, but is easily removed by wire brushing and scraping. The thin grey coloured oxide remaining on the gouged surface in no way interferes with or influences subsequent welding operations. There is no limit to the thickness of plate which can be flame gouged and in the case of light gauge work, a proficient operator should find no difficulty in working on $\frac{1}{4}$ in. or even $\frac{3}{16}$ in. material.

DISCUSSION.

MR. WALKER: I think you will agree that for the time at his disposal Mr. Clark has given us a very illuminating lecture, and as

we have just three minutes to spare, we want you to be as brief as possible with your questions.

MR. CASTLEDINE, Int. A.M.I.P.E. (Leicester Section): In the welding of Duralumin, I think the lecturer stated that, after welding, the strength of the section at the weld would be about 5 tons. Is it suggested that the strength of the Duralumin cannot be brought back by solution treatment ?

MR. CLARK : No sir, I would not suggest that. Strength can be re-introduced by heat treatment, but fabricated parts would be difficult to handle for this treatment and in any case the weld would have a cast structure. In the time at my disposal I can only generalize and not go into detail fully. You are probably aware of a special Duralumin recommended for welding known as Duralumin H, but this also suffers from some loss of strength due to the change of structure after welding. Some small amount of additional strength can be introduced by hammer forging. This must be done with care, otherwise undue hardening and brittleness will result.

MR. POLLOCK (The B.T.H. Co., Ltd.) : I am very interested in the Argon welding and I should like to know what range of thickness of metal can be joined by that method. Is it restricted in any way ?

MR. CLARK : Frankly Argonarc welding is not within my particular field. The process can be viewed as comparable to gas welding so far as thicknesses are concerned. For single pass welds on magnesium alloy sheet, the maximum thickness would be $\frac{1}{8}$ in., with superimposed runs on greater thicknesses ; the material should be bevelled for this. It should be mentioned that high frequency current is superimposed on the standard equipment ; this is desirable for starting and maintaining the arc. Both A.C. and D.C. equipments are used.

MR. TOPE, Grad. I.P.E. (Coventry Section) : Mr. Clark mentioned about the bevelling for thicker sheets, and he mentioned, I believe, that it was to be done fairly skilfully and accurately, and yet I noticed on the big door which was being repaired you mentioned that they did it by chiselling. Is that sufficiently accurate ?

MR. CLARK : The answer is that repair must not be confused with fabrication. The preparation of steel for fabrication should be precise. Cast iron is not usually associated with fabrication, and in any case cannot be flame cut with the same degree of accuracy. It is usual with repair work to chip, file or grind the bevel, but this should be done as accurately as possible.

MR. TOPE : Do you recommend machining the bevels when you say they should be very accurate ?

MR. CLARK : This is a wide and debatable field. Flame machining is, I believe, as cheap and as quick as mechanical machining if all aspects of each are considered. Planning machines work at considerable cutting speeds, but the idle return and the number of cuts have to be considered, material must be transported to and from the planning machine, perhaps some distance along the shop. With oxy-acetylene flame cutting, however, a small portable machine and two cylinders can be taken to the stock or welding site saving undue handling.

MR. LEEDHAM, M.I.P.E. (Leicester Section): What is the range of dissimilar metals which can be united on welding processes ?

MR. CLARK : Steel to brass, copper and cast iron and also any of these combinations. In addition, as you have seen, aluminium can be joined to steel ; it is also possible to join this metal to brass and copper in the same way. A bronze rod can be used for jointing steel to steel for conventional joints and very good results obtained.

MR. BROWN, A.M.I.P.E. (Coventry Section): You did touch upon the subject of deposition, but I am afraid time did not permit you to go fully into it. You mentioned a bronze weld you made on the cast iron door being repaired. Could you briefly give us your experience on the use of bronze type rods for metal deposition on various types of machines ?

MR. CLARK : If you mean for resisting wear, you can be assured that a bronze rod containing about 10% nickel will give extremely good frictional resistance, provided the working part is lubricated. Lubrication must be good to prevent seizure. So-called bronze rods should not be used to work against bronze owing to similarity of materials and expansion. Where pins are working in bronze bushes, a bronze rod should not be used unless it is known for certain that the bush is a genuine tin or phosphor bronze and not just a high class brass. "Bronze" rods are really 60/40 brass with or without other additions such as silicon, nickel or manganese.

MR. MILLS, Stud. I.P.E. (Coventry Section): In the Argon welding, can you use different metals and can you do it on aluminium as well ?

MR. CLARK : A dissimilar filler rod cannot be used, but the process is not limited to magnesium alloys. Some success is being achieved on stainless steel, brass and aluminium, but fluxes seem to be necessary. The main application at the moment is upon magnesium and this is the material which produces the worst flux corrosion condition.

MR. WALKER : Gentlemen, our time is up and I would call on Mr. Sinclair of Messrs. Alfred Herbert Limited to propose a vote of thanks.

MR. SINCLAIR, M.I.P.E. (Coventry Section) : Mr. Chairman, Ladies and Gentlemen—I should like to propose a very hearty vote of thanks to Mr. Clark for his lecture. I do not think I have ever heard so much information put over in so short a time and this information put over by a man who knows his job. I counted the number of times he referred to his notes, seven times. I think that he shows his knowledge of the subject by the way he has answered the questions. That is what one would expect from the British Oxygen Company Limited. I had the privilege of visiting them before the war and anything they do I know is first-class and the lecturers they send out are the same.

I propose a very hearty vote of thanks to Mr. Clark for his most instructive and excellent lecture, and while I am on my feet I should like to propose a very hearty vote of thanks to our Chairman, Mr. Walker, for officiating in the efficient manner he has done at this meeting.

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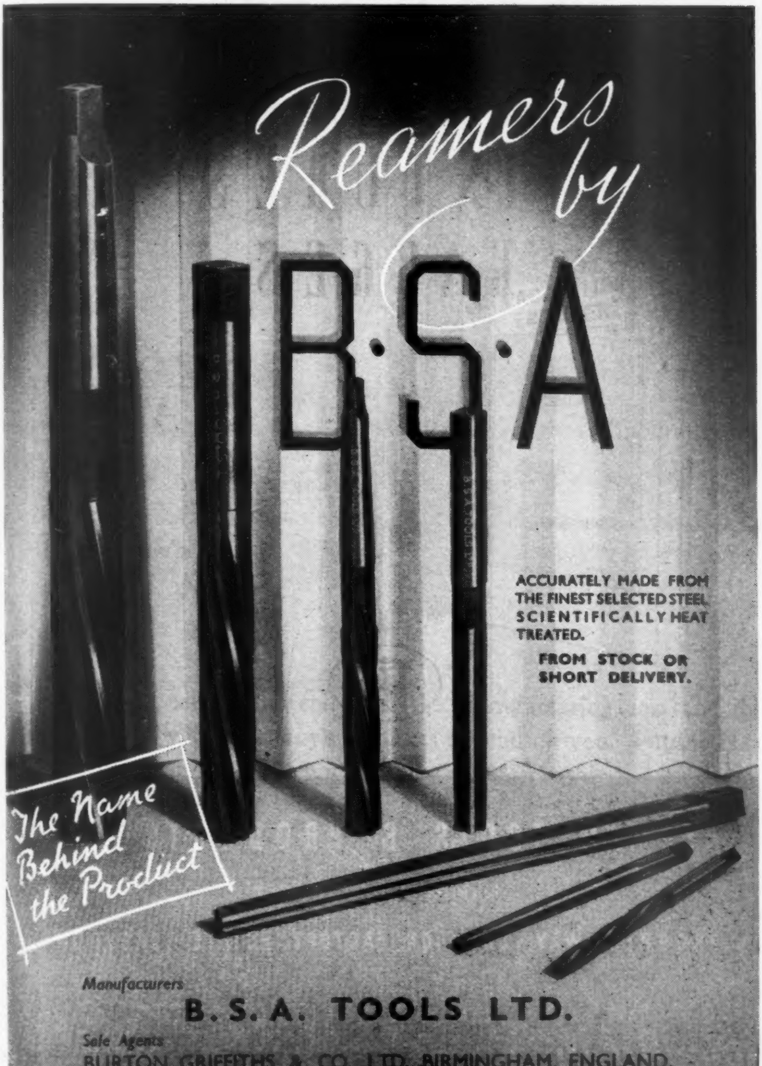
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